trials could be anticipated because of the differences in the age of the trees and in the employed rooting techniques. All the same, the results indicated good rooting trees within the same age groups. A number of trees also demonstrated ease of rooting in a series of trials. This was the case especially with P. griffithii X *strobus* trees which showed more consistency in rooting and had a better rooting average than P. strobus. Thus the possibility of selecting good rooters existed in trees 15-years old and younger, especially in the P. griffithii X strobus hybrid.

Conclusions

The observed variation in rooting of P. strobus and P. griffithii X strobus trees, and the consistency in rooting of some trees in a series of trials, allowed for the selection of easily-rootable white pines.

Abstract

Several rooting trials were established with cuttings of P. strobus and P. griffithii X strobus trees. Large variation in rooting was observed. The rooting of the same trees in different trials gave a good indication of the ease of rooting and resulted in the selection of easily-rootable types.

Key words: Vegetative propagation, white pine, blister rust, resistance.

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Estimates of General and Specific Combining Ability for Height and Rust Resistance From Single-Crosses of Slash Pine[1])

By John F. Kraus[2])

(Received March 1973)

Most progeny testing programs for forest trees are designed to obtain information about the breeding value of selected trees used in seed orchards. A high breeding value is usually considered a high general combining ability for the trait being tested.

Selection for high general combining ability assumes that each clone will cross-pollinate with a number of other clones and that the majority of the seed production from the orchard will be from such crosses.

Interest in specific combining ability is usually based on three considerations: (1) high specific combining ability is an indication of a relatively large amount of nonadditive variance affecting the trait under consideration, (2) the relative magnitude of specific combining ability can be important in determining the method of progeny testing used for assessing breeding value, and (3) in some instances high specific combining ability can be used to establish seed orchards which would utilize the dominant gene effects for the production of seed having potential for great improvement in one trait or for the production of special populations for advanced breeding programs.

The data presented here are from two 6-year-old progeny tests of slash pine (Pinus *elliottii* Engelm. var. *elliottii)* in which several trees have been crossed as female parents with five male parents as testers. Estimates are given for general combining ability (GCA) and specific combining ability (SCA) for total height and for the average number of fusiform rust cankers (Cronartium fusiforme Hedgc. and Hunt ex Cumm.) per surviving tree.

Materials and Methods

The parents used in both tests were selected trees represented as clones in the grafted seed orchards of the Georgia Forestry Commission. The progeny tests were established from seed produced by control-pollination in these orchards.

Test 1 contains progeny of 14 female parents crossed with five male testers. It was outplanted in an 8 by 8 balanced lattice and analyzed as a randomized complete block with nine replications.

Test 2 contains progeny of nine female parents crossed with five male testers. It was outplanted in a 7 by 7 balanced lattice and analyzed as a randomized complete block with eight replications.

Five-tree row plots were used in both tests. The plantings were established on abandoned farmland belonging to the Georgia Kraft Company in Houston County on the upper Coastal Plain in central Georgia.

Sixth-year average total height per plot and average number of cankers per tree per plot were used in an analysis of variance which followed the method of Beil and Atkins (1967).

There were 10 missing crosses in test 1 and four in test 2. Missing plot estimates were calculated for each cross X replication cell. The interaction of male and female effects was used as a measure of SCA.

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[1]) Research conducted in cooperation with the Georgia Forestry Commission, the Georgia Forest Research Council, and the Georgia Kraft Company.

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Results and Discussion

The overall means for the progeny data *(Table 1)* indicate that in test 1 the female parents Worth 1, Emanuel 1, and Wheeler 11 were all relatively good selections for both height growth and fusiform rust resistance. Of the male parents used in test 1, both McIntosh 3 and Tattnall 5 showed relatively good height growth but were only about average in their resistance to fusiform rust. On the low end of the scale, female parent Camden 3 and male parent Telfair 25 in test 1 were poor; both should be recommended for removal from the seed orchard.

Table 1. — Sixth-year half-sib progeny means from single-crosses of slash pine.

Test 1			Test 2		
Parents	Mean total height	Mean cankers per tree	Parents	Mean total height	Mean cankers per tree
	feet	*number*		*feet*	*number*
Females			*Females*		
Worth 1	13.89	5.0	Randolph 1	12.95	3.1
Emanuel 1	13.47	6.4	McIntosh 4	12.46	4.5
Wheeler 11	13.28	5.1	Terrell 2	12.26	2.3
Dodge 2	13.23	7.3	Telfair 16	12.10	4.9
Dodge 5	13.21	8.1	Telfair 8	11.94	4.5
Dodge 4	13.04	7.0	Dodge 10	11.94	4.4
Dodge 15	13.00	8.1	Telfair 23	11.63	4.4
Telfair 38	12.98	7.8	Telfair 25	11.14	6.3
Dodge 14	12.96	7.4	Wheeler 9	11.11	4.7
Dodge 8	12.87	7.5			
Ware 21	12.66	7.7			
Ware 8	12.41	7.4			
Mitchell 7	12.14	8.6			
Camden 3	11.83	10.7			
Males			*Males*		
McIntosh 3	13.48	7.1	Tattnall 5	12.33	4.6
Tattnall 5	13.24	7.4	McIntosh 3	12.07	4.2
Lanier 1	13.01	7.6	Lanier 1	11.93	4.3
Ware 14	12.83	6.6	Wheeler 7	11.71	4.5
Telfair 25	12.08	8.5	Ware 14	11.69	4.2
Grand means	12.93	7.4		11.98	4.3

In test 2, female parents Randolph 1 and Terrell 2 would probably be the most desirable parents for future breeding — Terrell 2 principally for its relatively good resistance to fusiform rust. Among the male parents in test 2, both Tattnall 5 and McIntosh 3 again produced progeny having the best height growth but only average rust resistance. Telfair 25, used both as a male parent in test 1 and as a female parent in test 2, ranked low for height growth and very poor for fusiform rust resistance.

The analysis of variance for combining ability showed both SCA and GCA effects to be highly significant for both height and number of cankers per tree in test 1 *(Table 2)*. In test 2, the female GCA effects were highly significant for both height and number of cankers per tree and the SCA effects were significant for number of cankers per tree but not for height growth. The general lack of male effects in test 2 may have resulted from omission of the relatively poor male parent Telfair 25 and the substitution of an average male parent.

The variance components estimated from the mean squares show a preponderance of GCA, especially for height growth *(Table 2)*. The relative importance of additive and nonadditive genetic effects is indicated by the ratio GCA : SCA. For total height, the general effects averaged about 3-½ times larger than the components for specific effects. The data for fusiform rust show the general effects to be almost twice as large as the specific effects.

The SCA values are of little utility in themselves except to show the magnitude of variation in effects. If it were desired to select the best parents for use in a two-clone orchard, or to repeat some controlled-crosses for use in a seedling seed orchard, the selection would be based on the best GCA + SCA, which would be the cross with the best mean value. For example, in *Table 3* the cross Worth 1 × McIntosh 3 would have the highest mean, while the cross Ware 8 × Telfair 25, with the highest SCA value, has a mean total height well below average.

For rust resistance in test 1, the best cross is probably Worth 1 × Tattnall 5 *(Table 3)*. The Wheeler 11 × Lanier 1 cross has the same total GCA + SCA because of its slightly better SCA value.

A similar situation exists in test 2 where the best cross combination for height growth is Randolph 1 × Tattnall 5, and the cross Terrell 2 × Lanier 1 has the most favorable GCA + SCA total for rust resistance *(Table 4)*.

These tests indicate that, since the preponderance of genetic variation was due to GCA effects, the estimation of parental breeding value could be accomplished by one of the more economical progeny testing methods, such as open-pollinated seed orchard seed or controlled polycross seed. That is, if SCA is low, any male tester is suitable if its effect is reasonably uniform. With wind-pollinated ortet seed, there is risk of female comparisons being confounded by the different male effects and possibly by geographic effects. The risk is not eliminated but greatly lessened when seed orchard or polycross seed are used.

The relatively lower ratios of GCA : SCA for fusiform rust resistance indicate that a higher proportion of the genetic variance for this trait results from nonadditive gene effects. This also means there is more justification for establishing speciality seed orchards for rust resistance than for height growth. Such speciality orchards have been established under the North Carolina State University Cooperative Tree Improvement Program (N. C. State Univ. 1971, p. 27).

Summary

Date from 6-year-old single-cross progenies of slash pine were used to estimate effects of general and specific combining ability. Highly significant differences among general combining ability (GCA) effects were obtained for average total height and average numbers of fusiform rust cankers per tree. Specific combining ability (SCA) effects were highly significant for both traits in one test plantation and significant for fusiform rust infection in another.

The variance components for total height GCA averaged about 3-½ times larger than those for SCA. For fusiform rust infection, the variance components for GCA were twice as large as those for SCA.

Results indicate that, with the relatively large proportion of the genetic variance resulting from GCA effects, parental breeding value can be estimated from progeny tests of open-pollinated or polycross seed. The GCA : SCA ratios also indicate that utilization of SCA effects is more likely to be successful in breeding for fusiform rust resistance than for height growth.

Key words: Pinus elliottii, general combining ability, specific combining ability, fusiform rust resistance, height.

Table 2. — Analysis of variance of combining ability, variance components for GCA and SCA, and the GCA : SCA ratio in slash pine.

Source of variation	d. f.	Test 1		d. f.	Test 2	
		Mean squares			Mean squares	
		Height	Cankers per tree		Height	Cankers per tree
GCA[1]) (male effects)	4	36.112**	61.222**	4	5.146	2.692
GCA (female effects)	13	12.813**	89.242**	8	14.199**	49.887**
SCA (male × female)	52	2.751**	15.788**	32	2.230	7.266*
		Variance Components				
σ^2 males (GCA)		0.265	0.361		0.040	0.0
σ^2 females (GCA)		.224	1.632		.299	1.066
σ^2 m × f (SCA)		.182	1.261		.075	.458
Ratio, GCA : SCA		2.69	1.58		4.52	2.33

[1]) GCA = general combining ability; SCA = specific combining ability.

Table 3. — Estimates of GCA and SCA effects for sixth-year total height and number of cankers per tree of single-cross matings of slash pine, test 1

Females	**Males**					**General effect of females**
	McIntosh 3	**Tattnall 5**	**Lanier 1**	**Ware 14**	**Telfair 25**	
			Specific effects[1]			
Worth 1	.44(-0.9)	-.16(-1.5)	-.50(0.8)	.73(0.2)	-.49(1.5)	.96(-2.4)
Emanuel 1	-.25(0.4)	.31(-1.0)	.21(0.4)	-.01(0.7)	-.24(-0.6)	.54(-1.0)
Wheeler 11	-.05(0.2)	.18(-0.2)	-.11(-1.8)	.02(0.2)	-.04(1.4)	.35(-2.3)
Dodge 2	-.70(2.8)	.76(-1.4)	.03(0.3)	-.64(-1.0)	.54(-0.9)	.30(-0.1)
Dodge 5	.56(-1.3)	-.34(2.8)	-.02(2.8)	.09(-1.8)	-.26(-2.8)	.28(0.7)
Dodge 4	.13(0.9)	.12(0.0)	.42(-1.0)	.57(-0.9)	-1.25(0.7)	.11(-0.4)
Dodge 15	-.19(-0.4)	-.59(0.7)	.01(-0.9)	.00(0.2)	.76(0.3)	.07(0.7)
Telfair 38	-.14(1.7)	-.12(-0.3)	-.34(0.3)	.32(-0.6)	.29(-1.3)	.05(0.4)
Dodge 14	-.16(0.1)	.35(0.1)	.35(-0.1)	.01(0.2)	-.52(-0.4)	.03(0.0)
Dodge 8	.80(-1.4)	.33(-0.2)	-.22(-0.2)	-.61(0.5)	-.27(1.2)	-.06(0.1)
Ware 21	.42(-0.6)	-.83(0.0)	-.26(0.5)	.81(-0.1)	-.11(-0.1)	-.27(0.3)
Ware 8	-.34(0.1)	.16(0.1)	-.24(-0.1)	-.45(0.1)	.86(-0.4)	-.52(0.0)
Mitchell 7	-1.10(0.7)	.50(-0.9)	-.07(0.5)	-.10(0.7)	.80(-1.2)	-.79(1.2)
Camden 3	.67(-2.3)	-.68(1.7)	.79(-2.5)	-.68(1.1)	-.08(2.1)	-1.10(3.3)
General effect of males	.55(-0.3)	.31(0.0)	.08(0.2)	-.10(-0.8)	-.85(1.1)	

1/ First value shown is for total height; value in parenthesis is for number of cankers per tree.

Table 4. — Estimates of GCA and SCA effects for sixth-year total height and number of cankers per tree of single-cross matings of slash pine, test 2.

Females	**Males**					**General effect of females**
	Tattnall 5	**McIntosh 3**	**Lanier 1**	**Wheeler 7**	**Ware 14**	
			Specific effects[1]			
Randolph 1	.16(-0.3)	-.02(0.8)	.01(-0.8)	.12(-0.3)	-.28(0.6)	1.00(-1.2)
McIntosh 4	-.46(-0.2)	-.38(-0.1)	-.40(1.2)	1.16(-0.4)	.08(-0.1)	.51(0.2)
Terrell 2	.52(-0.5)	-.29(0.7)	.32(-0.4)	-.38(-0.3)	-.17(0.2)	.31(-2.0)
Telfair 16	.07(-0.2)	.37(0.2)	-.75(0.4)	.30(-0.6)	.02(-0.2)	.15(0.6)
Telfair 8	.09(-0.8)	.04(-0.1)	.01(0.2)	.54(0.5)	-.70(0.0)	-.01(0.2)
Dodge 10	.65(0.1)	-.04(0.0)	-.35(0.8)	-.25(-1.7)	.00(0.7)	-.01(0.1)
Telfair 23	-.27(0.4)	.14(0.0)	-.36(-0.1)	-.30(0.0)	.80(-0.3)	-.31(0.1)
Telfair 25	-.56(0.8)	.57(-1.9)	.31(-1.2)	-.53(3.3)	.20(-1.1)	-.81(2.0)
Wheeler 9	-.20(0.5)	-.39(0.0)	1.21(-0.5)	-.66(-0.1)	.04(-0.2)	-.84(0.4)
General effect of males	.38(0.3)	.12(-0.1)	-.02(0.0)	-.24(0.2)	-.26(-0.1)	

1/ First value shown is for total height; value in parenthesis is for number of cankers per tree.

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Pollination of Teak (Tectona grandis L.). 2.

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1. Introduction

Initial pollination investigations conducted in 1965—66 at the Teak Improvement Center, Thailand were reported in 1969 by Bryndum & Hedegart (1969).

The present paper summarises research activities during the period 1967—72. These concentrated on development of isolation and pollination procedures.

2. Natural Pollination

2.1 Pollinating insects

As previously suggested by Bryndum & Hedegart (1969) insects are believed to be the major agents of teak pollination. A closer examination of insects visiting teak flowers was undertaken in 1967 and 1968.

Observation scaffoldings were erected at four middle aged trees, the distance between the trees varying from 1.5 km to c. 16 km. The scaffoldings were visited frequently every day during the flowering period (July)-August-September. Records were kept of the number of flowers at each inflorescence marked for observation the temperature, wind and cover of clouds. During each visit 10 minutes were spent by each inflorescence counting the number of visiting insects according to the categories indicated in *table 1*. A number of insects were caught in small glass tubes. Five anthers, one from each of five flowers, were likewise collected from each inflorescence.

In the laboratory the insects were examined for pollen under microscope (25—50 ×). A summary of the observations is presented in *table 1*.

A known amount of distilled water was added to each category of insects. After light shaking for two minutes, four drops were taken for examination of the quantities of pollen under the microscope (75 ×). A "pollen index" was calculated from:

Amount of water (mm^3)/No. of insects (or anthers) ×
No. of pollen grains/Observation square (mm^2).

The same procedure was applied in calculating pollen indices for the collected anthers.

Figure 1 shows average pollen indices for anthers for the hours of the day, compared with the average number of visiting insects during the same periods.

In *table 2* is calculated a "pollinator value" for each species (or group) of insects. These values are for each category based on the average pollen index for all insects caught and the average number of visiting insects during the 10-minute observation periods.

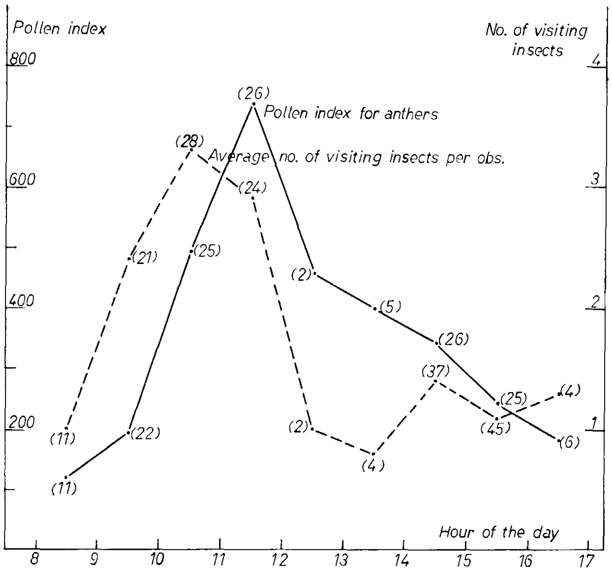

Figure 1. — Average pollen indices for anthers for the individual hours of the day, compared to average number of visiting insects per observation of 10 min. Pollen index = Amount of water (mm^3) / No. of anthers × No. of pollen grains / Observation square (mm^2). Figures in brackets indicate number of observations.

Table 1. — Insects visiting teak flowers distributed by the amount of pollen carried.

Insect species (or group)	Total no. examined	None		Insects carrying amount of pollen A little		Much		Very much	
		No.	%	No.	%	No.	%	No.	%
Heriades parvula	57	2	3.5	15	26.3	13	22.8	27	47.4
Ceratina hieroglyphica	18	3	16.7	7	38.8	3	16.7	5	27.8
Other bees	12	4	33.3	5	41.7	2	16.7	1	8.3
Ants	154	96	62.3	56	36.4	2	1.3	0	0
Other insects	106	71	67.0	34	32.1	1	0.9	0	0